National Aeronautics and Space Administration

Radiometric System Model for RBI

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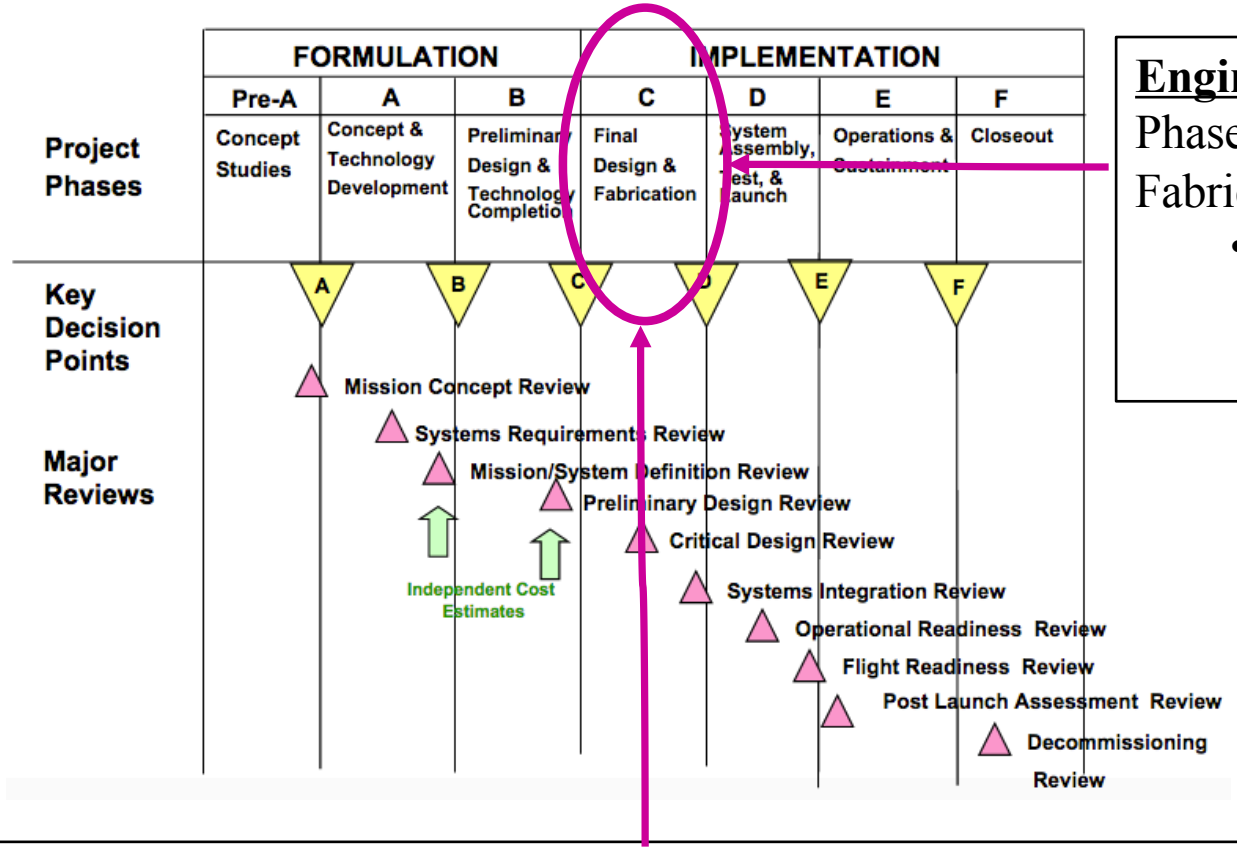
Radiometric System Model Objectives

Develop a tool to enhance the interpretation of Instrument performance

- Model the end-to-end science signal chain: Photons in to bits/counts out.

- Simulate the science data stream output when viewing *calibration targets*, *earth scenes* or any *user-defined radiance*.
- Support and validate engineering design and fabrication phase
- Quantify the effects of various anomalous sources of energy: stray light
- Perform analyses as required to evaluate and quantify the impact to science data due to other uncertainties.

Current RBI Project Phase



Engineering-Led Effort

Phase C: Final Design and Fabrication

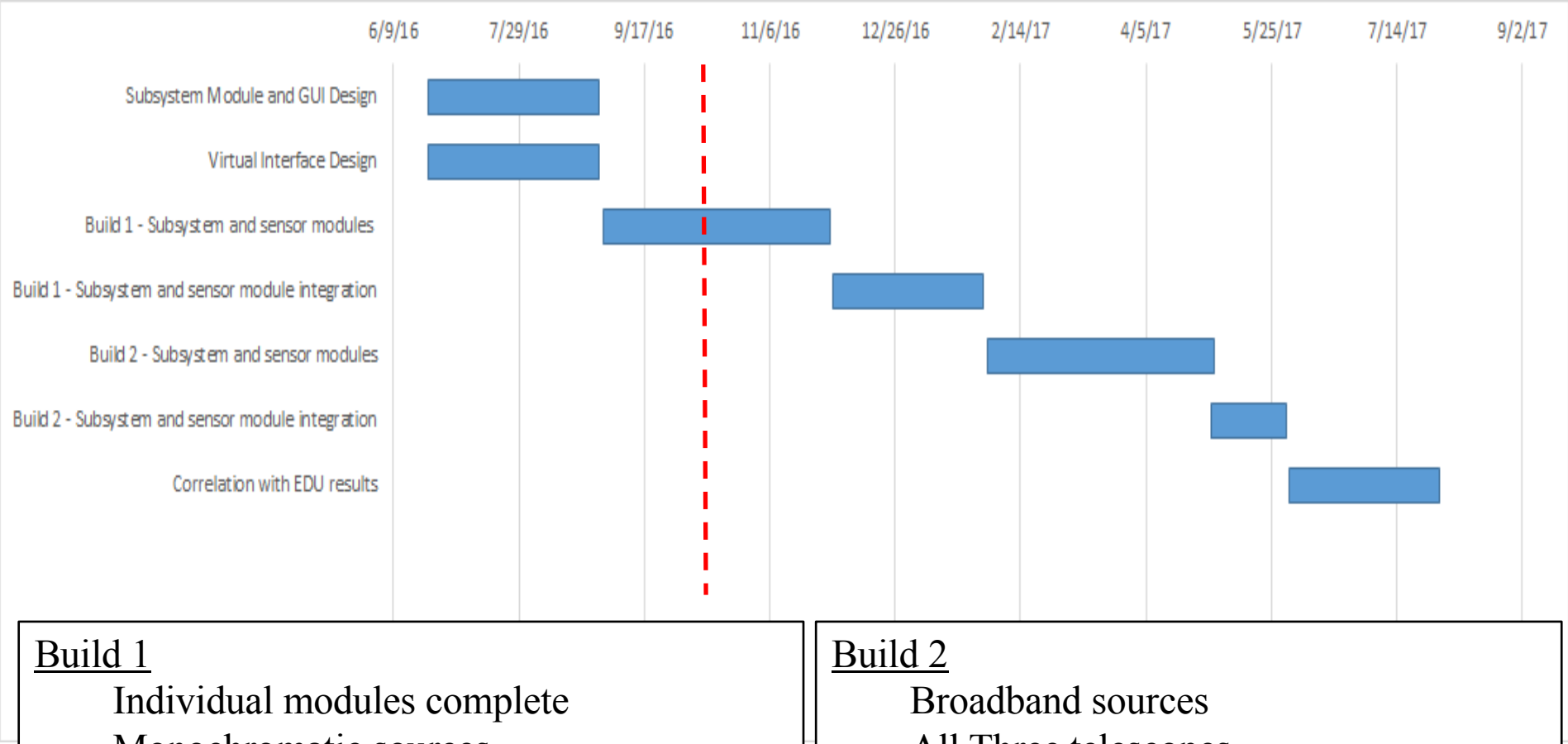
- Demonstrate that the detailed system design meets requirements

Science-Led Effort

Develop the end-to-end model of the science signal chain: Photons in to bits/counts out.

- To be correlated to the Engineering Development Unit at the end of Phase C
- To be correlated to the Flight Unit at the end of Phase
- Support Mission Operations and Data Analysis in Phase E

Model Development Schedule



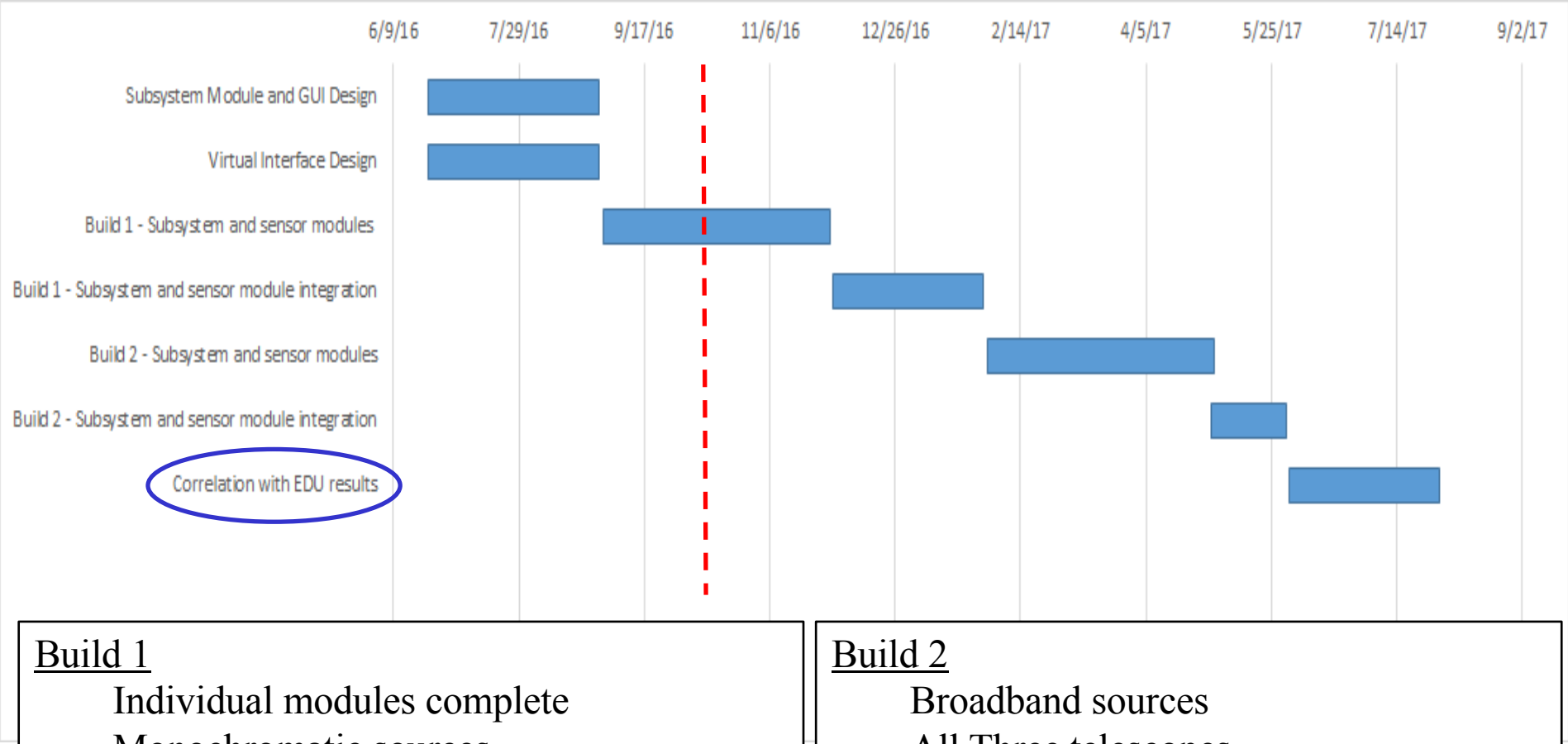
Build 1

- Individual modules complete
- Monochromatic sources
- Single telescope (Total)
- Single sided
- GUI

Build 2

- Broadband sources
- All Three telescopes
- Double sided

Model Development Schedule



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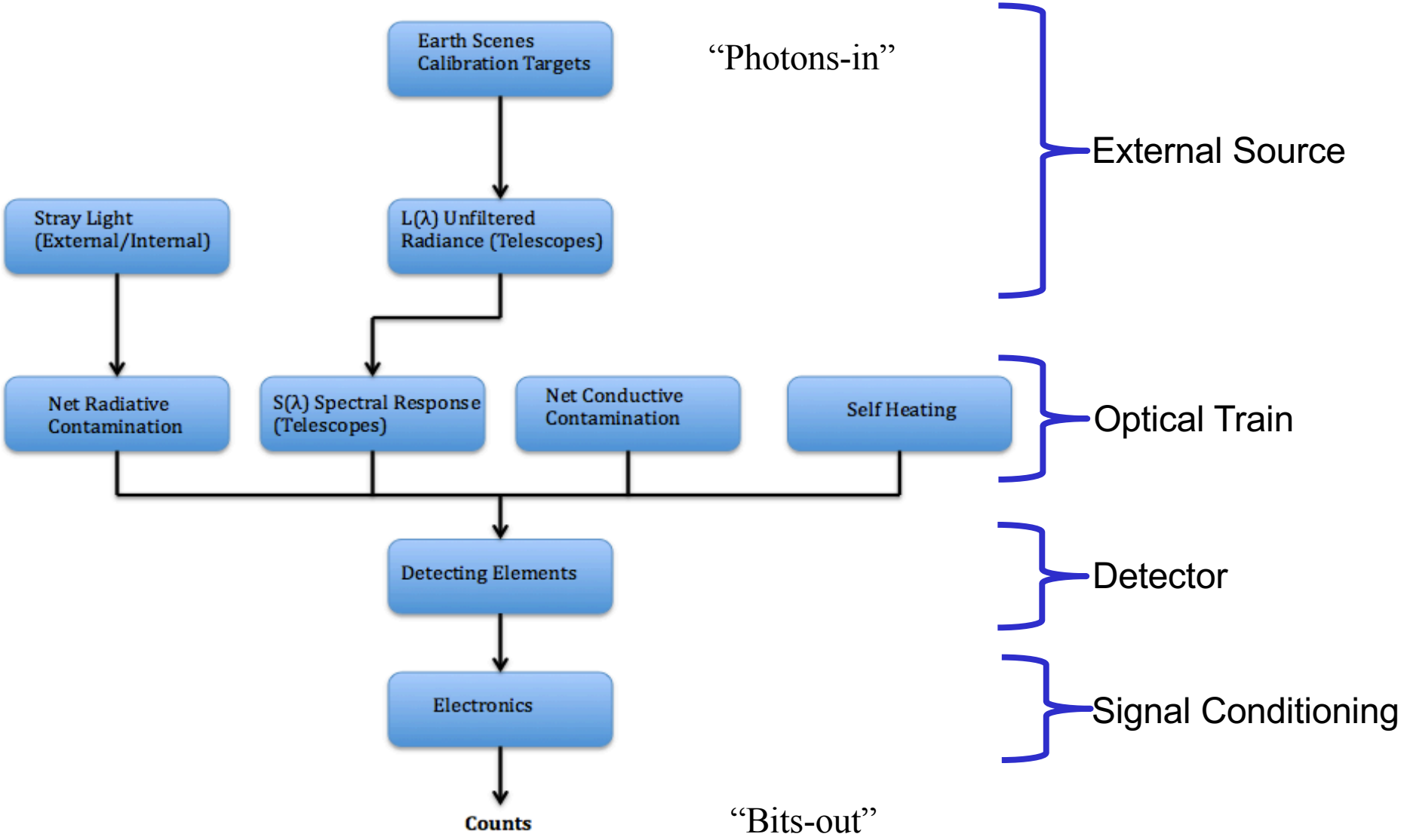
Typical Instrument Analytical Model



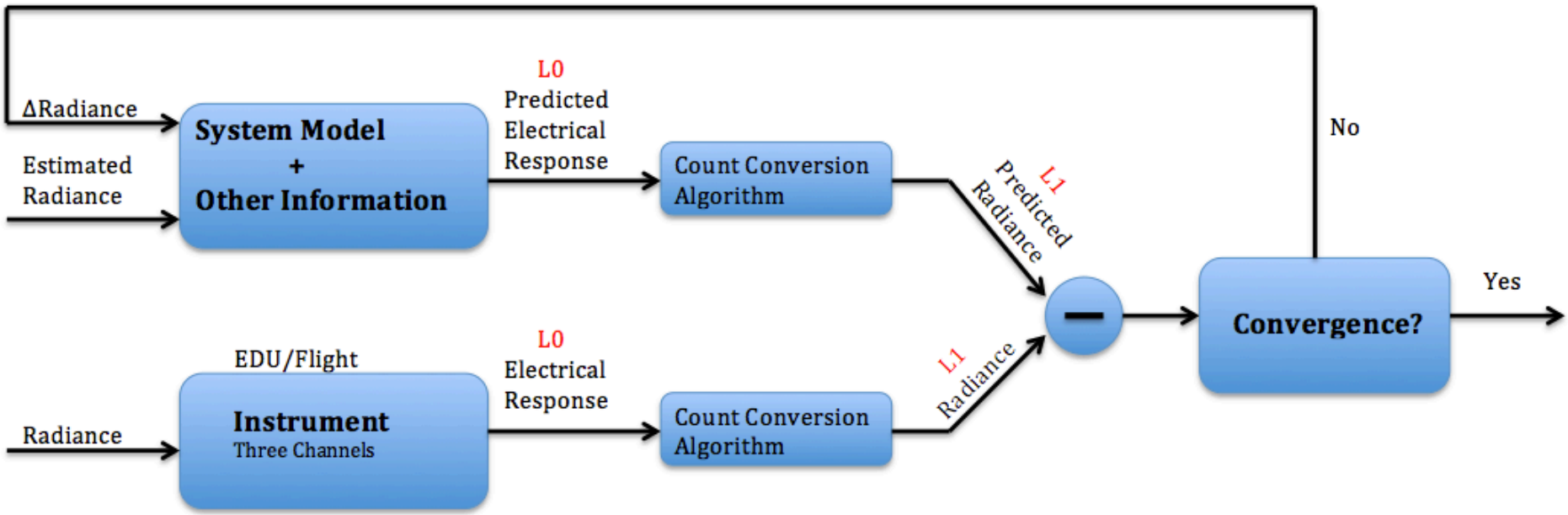
Numerical Modeling Tools

- Monte-Carlo Ray-Trace Model
  - Computes the distribution of radiation within the instrument.
  - Spectral characterization of the optical and radiative performance of the entire instrument.
  - Provides the necessary “Boundary” conditions for the thermal models.
- Finite-Element Thermal Diffusion Model
  - Three-Dimensional characterization of the transient thermal diffusion in instrument components
- Finite-Difference Electro-thermal Model
  - Three-Dimensional characterization of the transient thermal diffusion in the detectors
  - Two-Dimensional characterization of the transient electrical diffusion in the thermocouples.
- Electrical Circuit Model
  - Computation of the electronic Response of the electrical feedback control system.

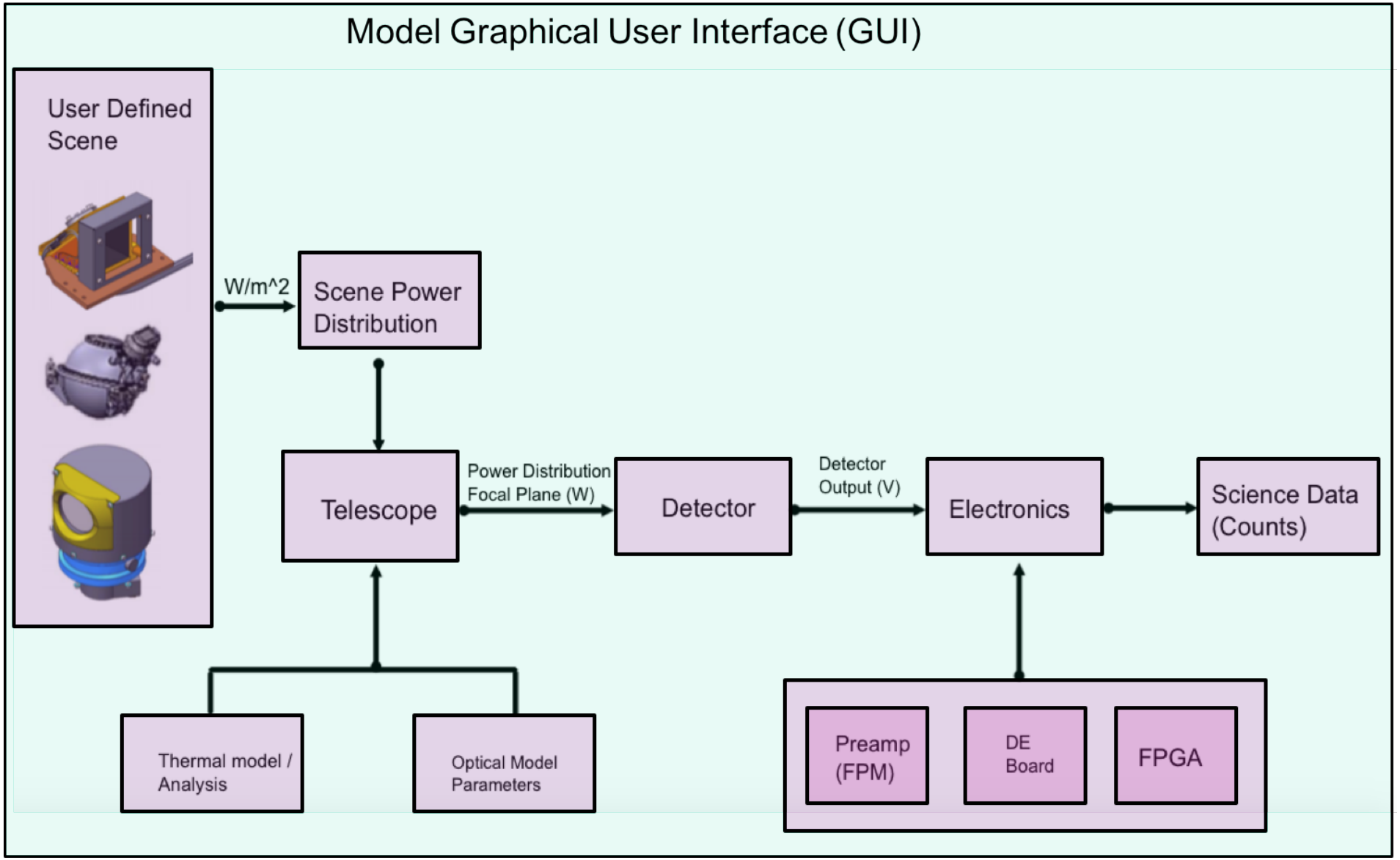
Previous Earth Radiation Budget (ERB) programs, such as CERES, have used these modeling tools for End-to-End characterization of the instrument

Correlation of Model to Hardware

- During System Level TVAC testing we will simulate the test execution with the model to complete an end-to-end correlation.
- If the Model and Hardware do not converge, we will perturb model parameters within their allowed tolerances to bring the model and hardware into agreement.



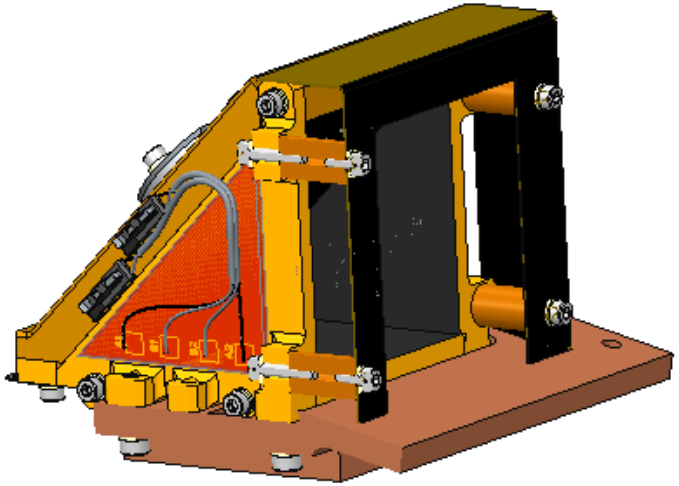
RBI Instrument End-to-End Model



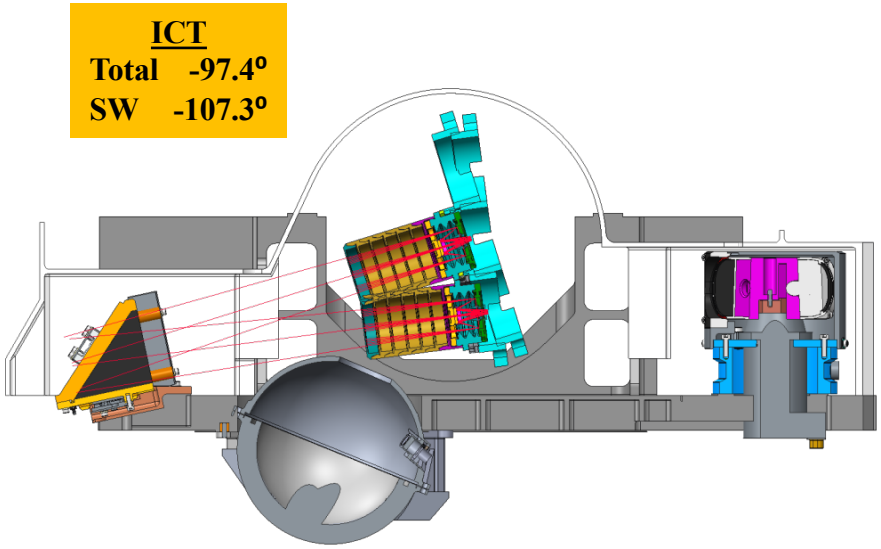
Sources

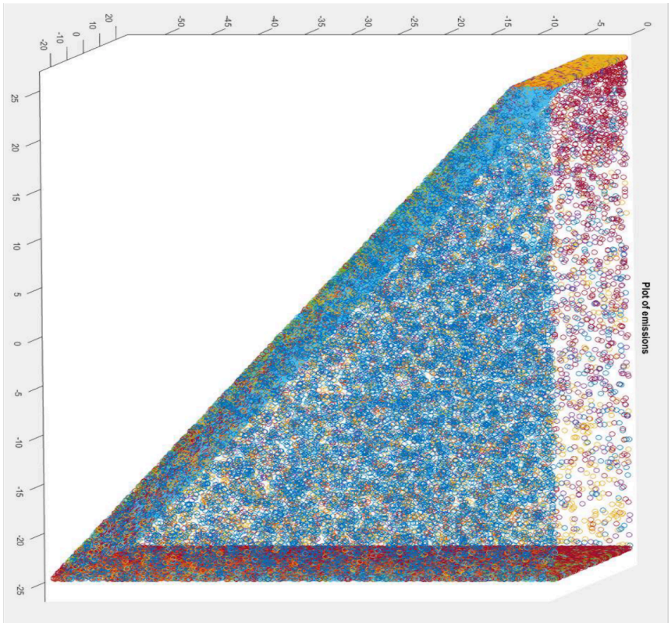
- On-board Calibration sources are currently being modeled with MATLAB and/or Zemax Optics Studio
  - **Infrared Calibration Target (ICT)** - Using MCRT techniques to compute the distribution of radiation within the ICT and as distributed on the telescope aperture.
  - **Visible Calibration Target (VCT)** - Similar techniques as the ICT
  - **Solar Calibration Target (SCT)** – Similar techniques as the ICT
- Parameters such as optical prescription, viewing geometry, and paint specs are also being modeled.
- Thermal analysis are being conducted in parallel.

Infrared Calibration Target Module

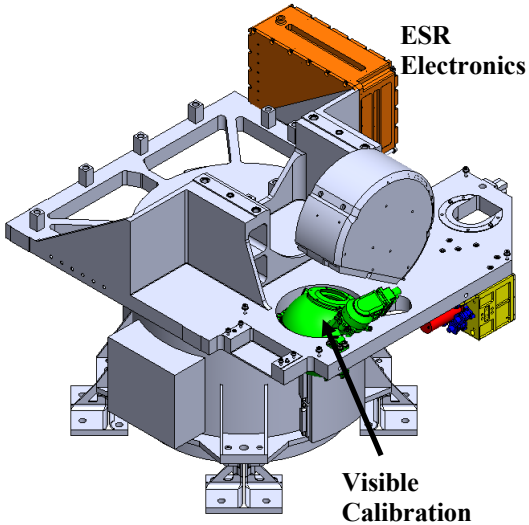


- ICT positioned to be viewed by both Total and Longwave Detectors
- ICT spatial and spectral output distribution imaged on the Focal Plane
- Thermal gradients within the ICT can produce ambiguous radiance
- Degradation of Z-302 will reduce effective emissivity over lifetime

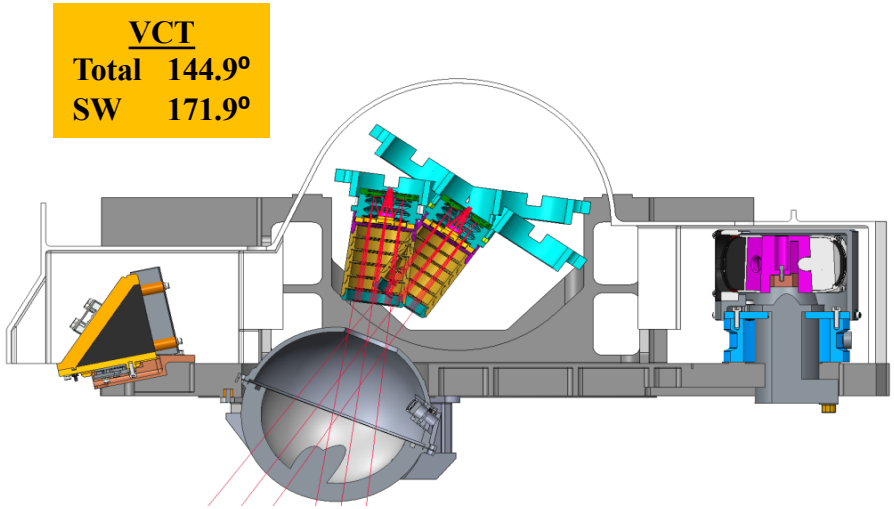




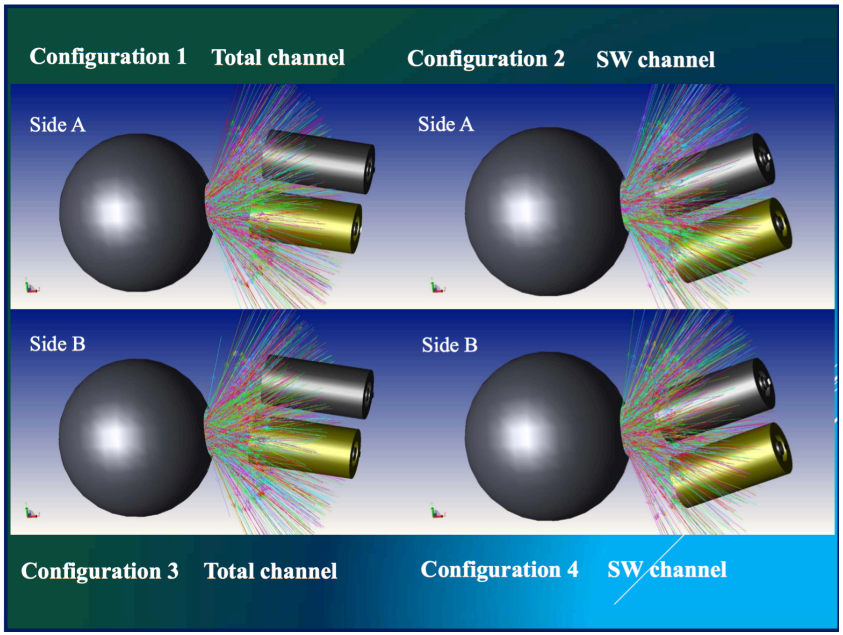
Visible Calibration Target Module



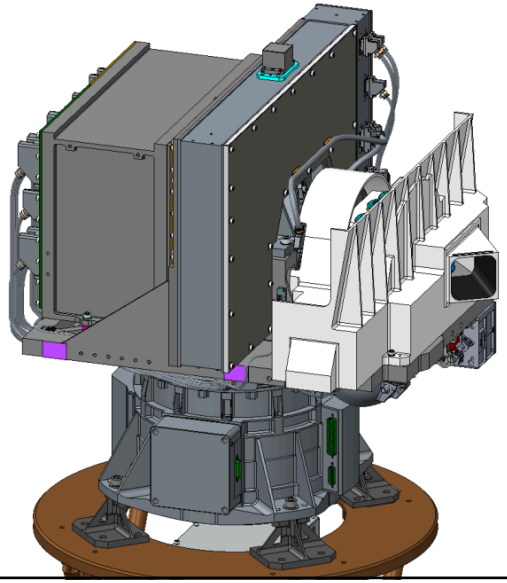
- VCT positioned to be viewed by both Total and Shortwave Detectors
- VCT spatial and spectral output distribution imaged on the Focal Plane
- Thermal gradients within the VCT can produce IR background signal on the Total Channel



Visible Calibration Target (VCT)

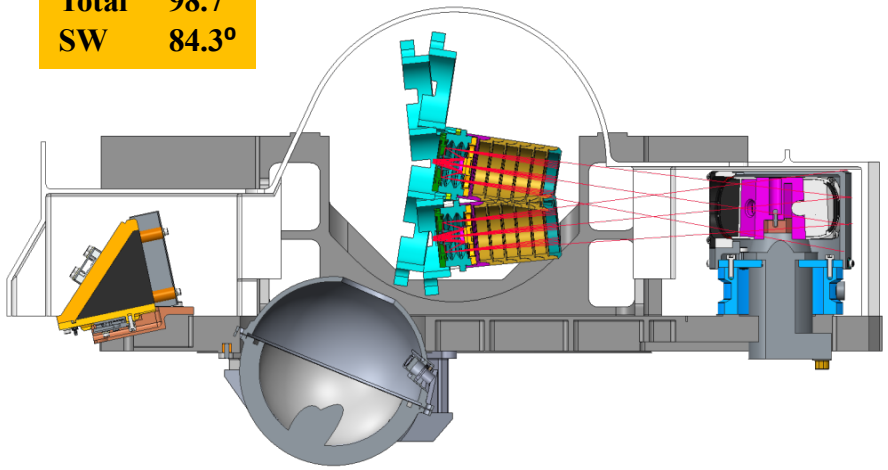


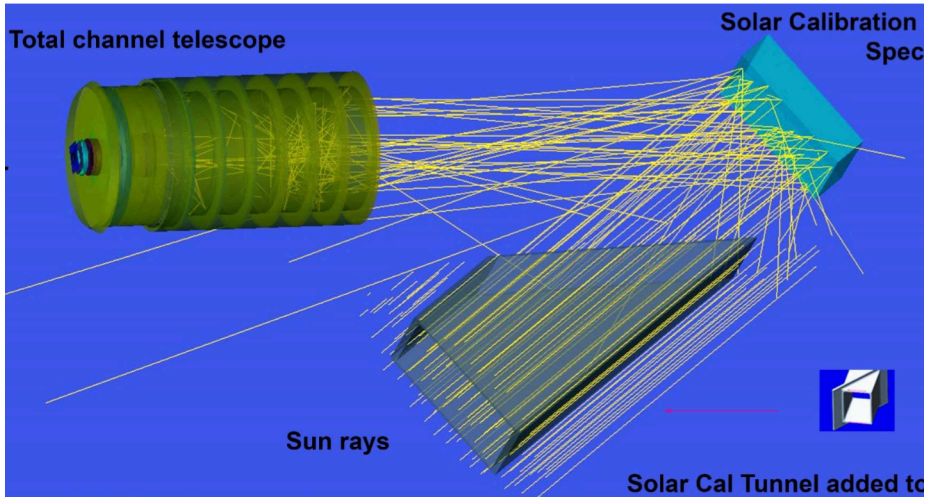
Solar Calibration Target Module



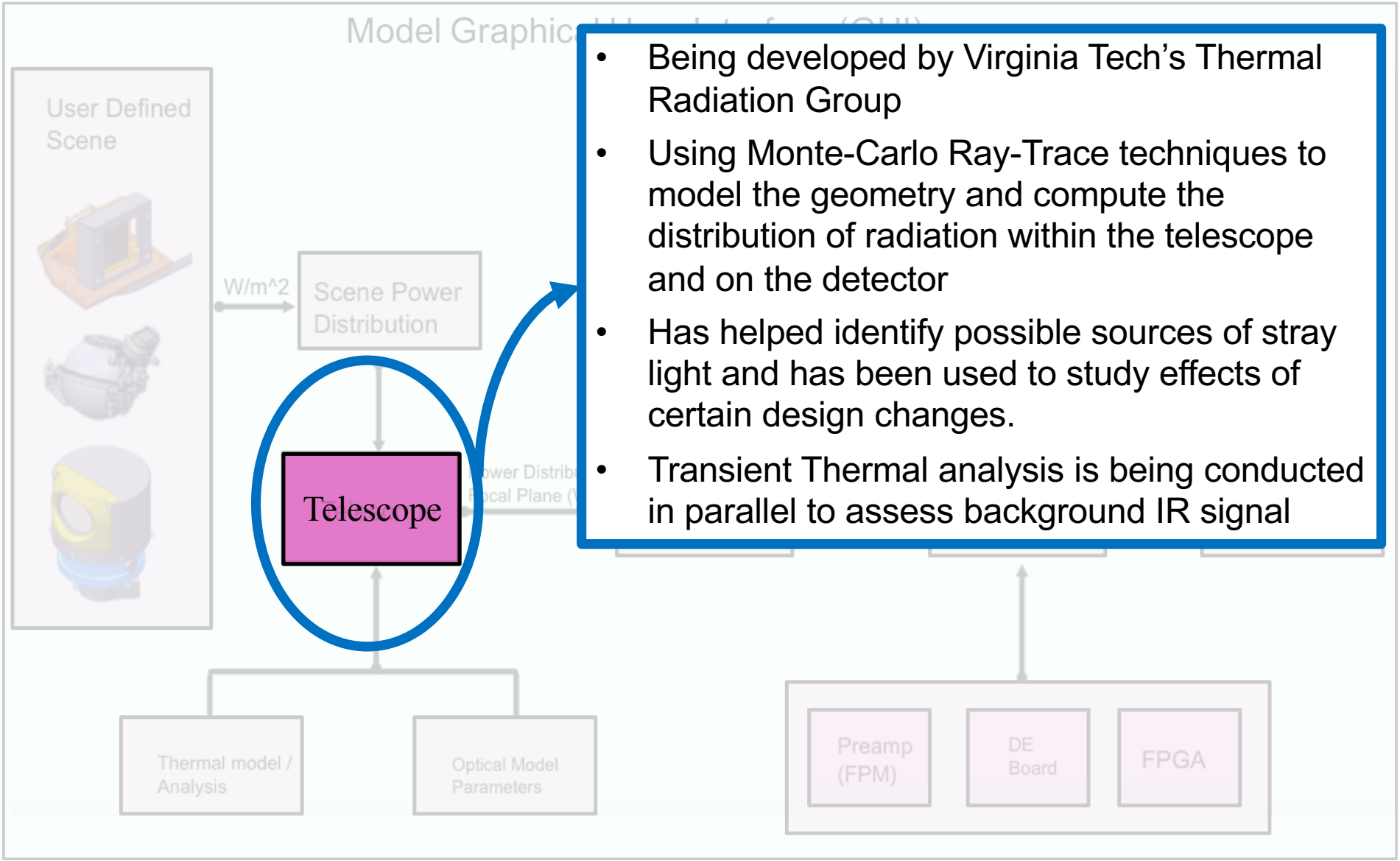
- SCT positioned to be viewed by both Total and Shortwave Detectors
- SCT spatial and spectral reflected radiance distribution imaged on the Focal Plane
- Thermal gradients across the SCT can produce IR background signal on the Total Channel

SCT	
Total	98.7°
SW	84.3°





Optical Module



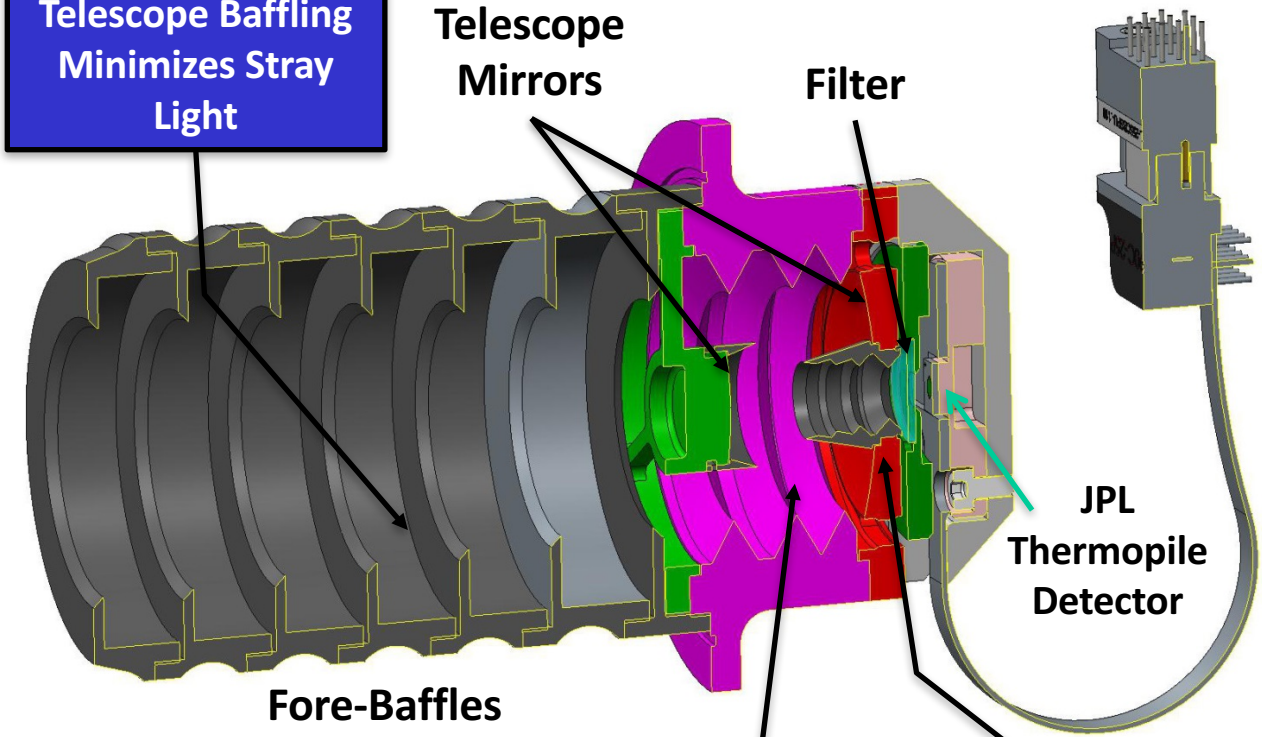
- Being developed by Virginia Tech's Thermal Radiation Group
- Using Monte-Carlo Ray-Trace techniques to model the geometry and compute the distribution of radiation within the telescope and on the detector
- Has helped identify possible sources of stray light and has been used to study effects of certain design changes.
- Transient Thermal analysis is being conducted in parallel to assess background IR signal

Optical Module

Extensive Telescope Baffling Minimizes Stray Light

Telescope Mirrors

Filter

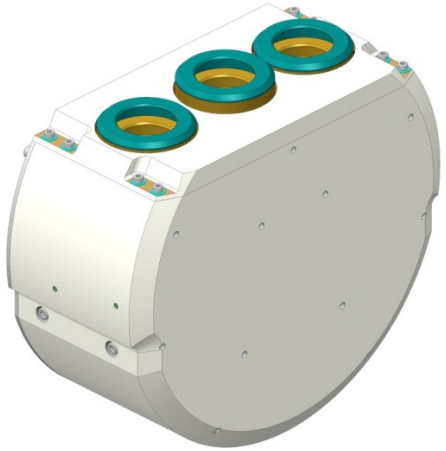


JPL Thermopile Detector

Fore-Baffles

Materials Minimize Thermal Gradients

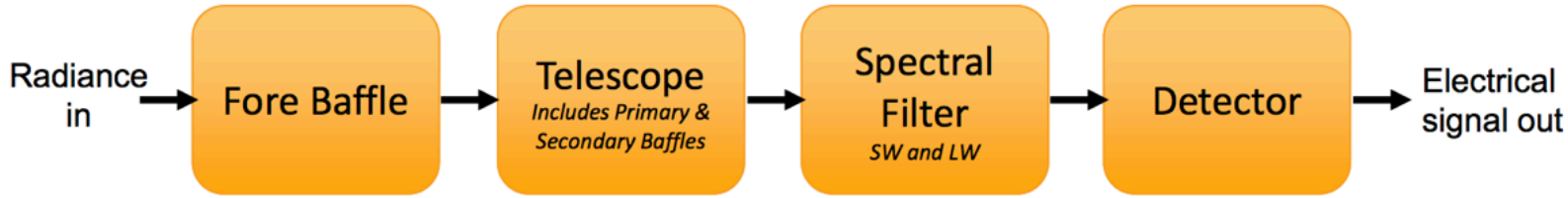
Rear Enclosure Provides Thermally Stable Environment

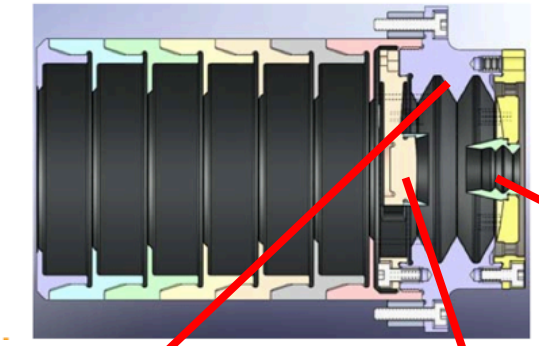


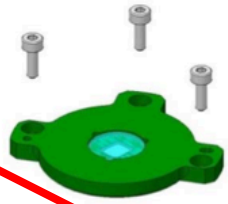
Optical Module

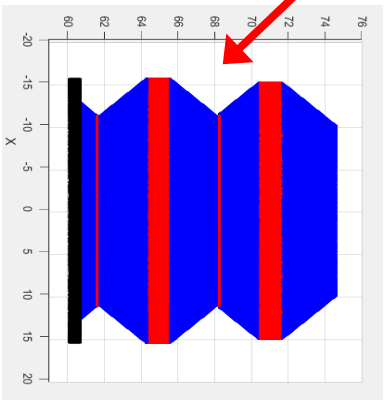
One Telescope Per Band Simplifies Detector Design

Optical Module

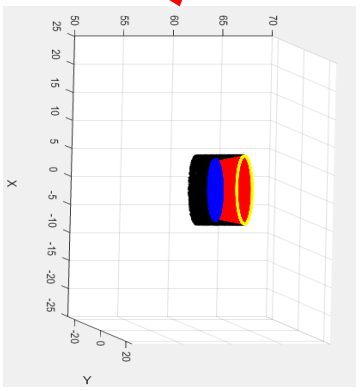




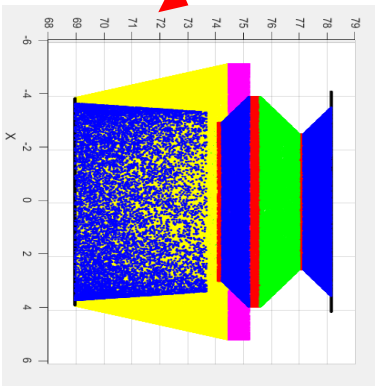




Telescope



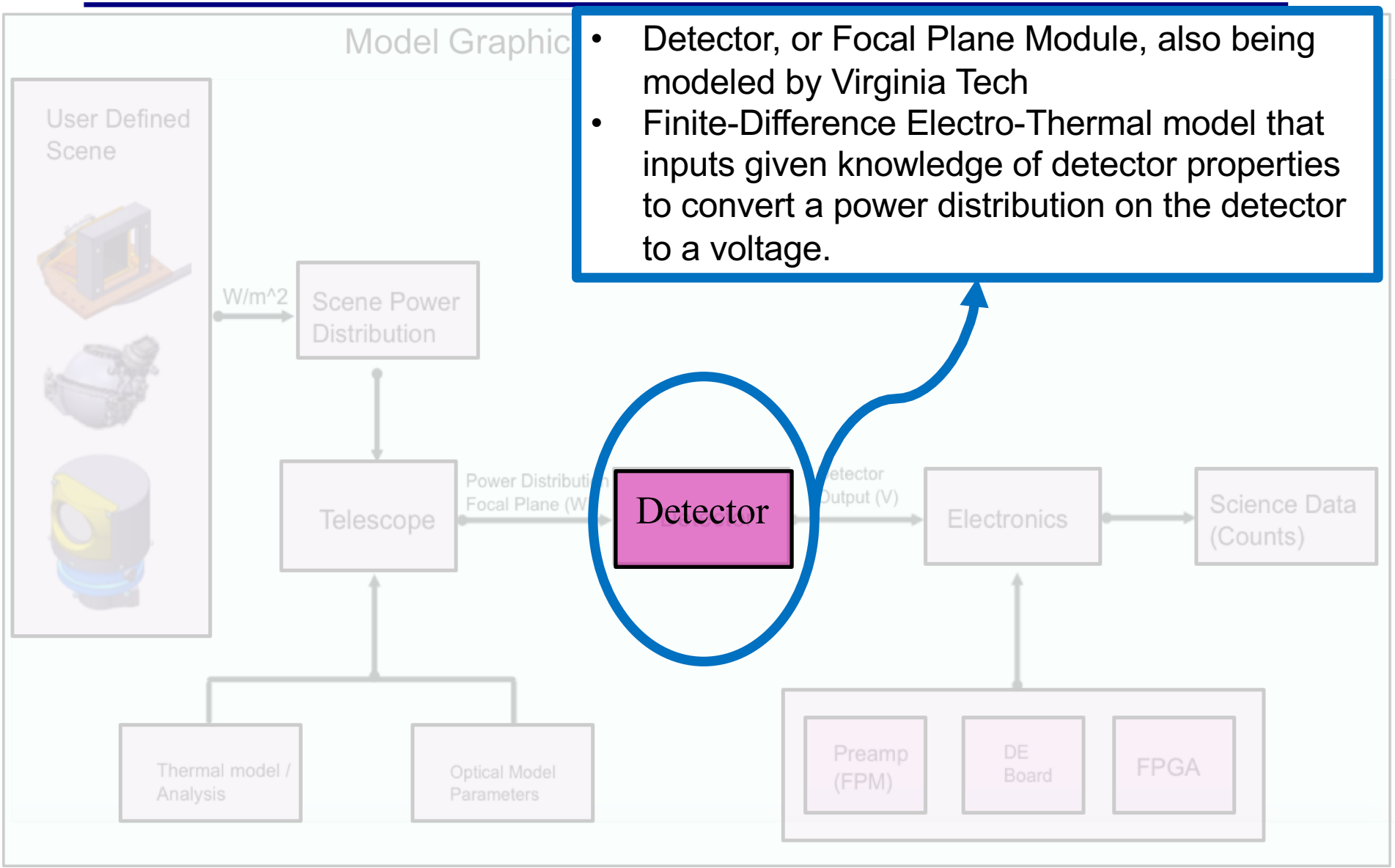
Secondary Mirror Baffle



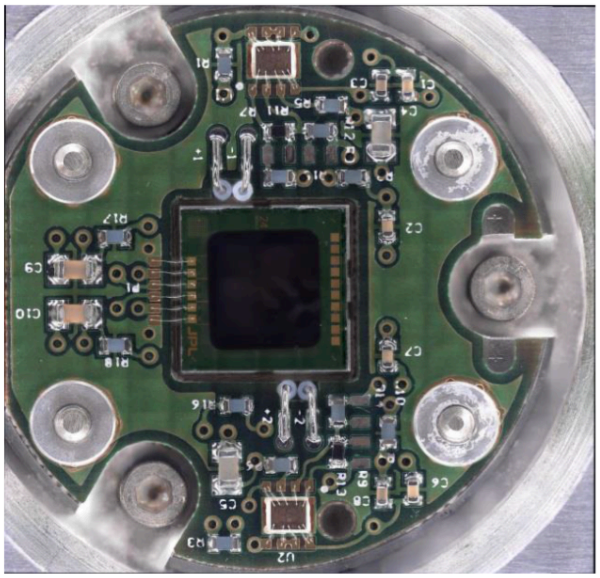
Primary Mirror Baffle

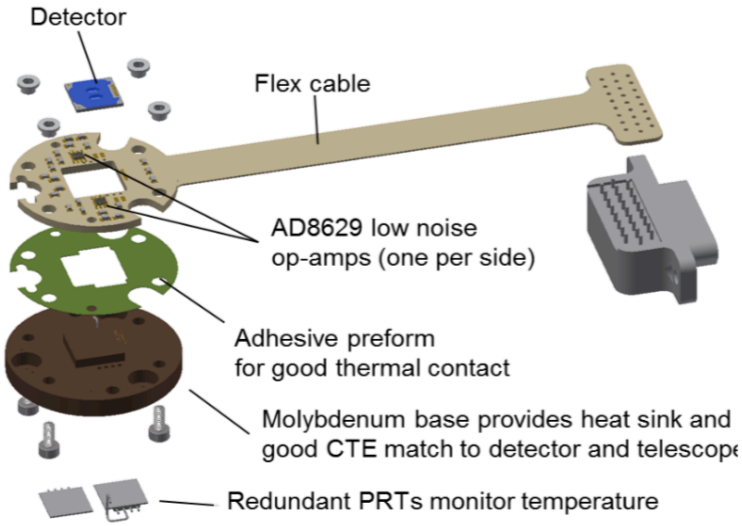
Focal Plane Model

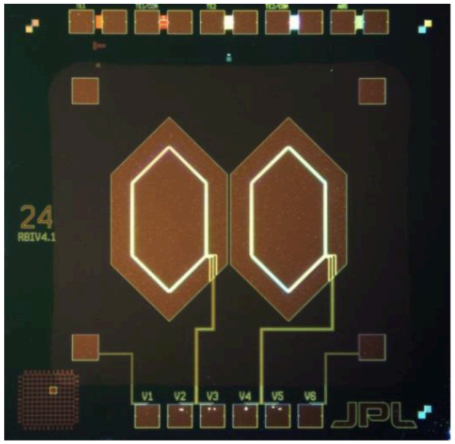
- Detector, or Focal Plane Module, also being modeled by Virginia Tech
- Finite-Difference Electro-Thermal model that inputs given knowledge of detector properties to convert a power distribution on the detector to a voltage.



Focal Plane Module





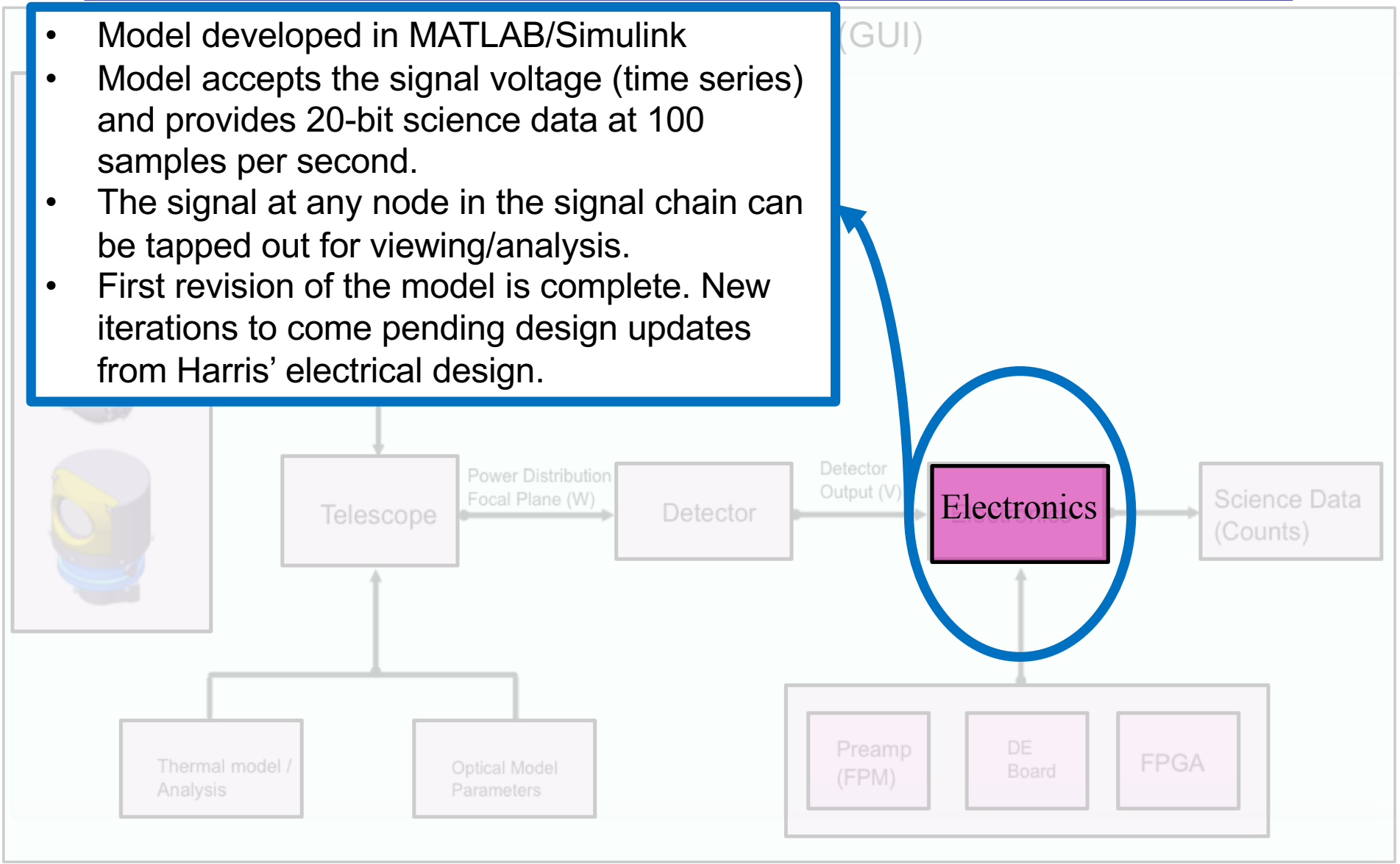


Focal Plane Module is a Thermal Detector that compares heat sink temperature with a membrane coupled to the radiation from the telescope

Passive Thermopile Detector
AD8629 single op-amp analog gain circuit
Customer supplied PRT for heat sink monitoring

Signal Conditioning Electronics

- Model developed in MATLAB/Simulink
- Model accepts the signal voltage (time series) and provides 20-bit science data at 100 samples per second.
- The signal at any node in the signal chain can be tapped out for viewing/analysis.
- First revision of the model is complete. New iterations to come pending design updates from Harris' electrical design.



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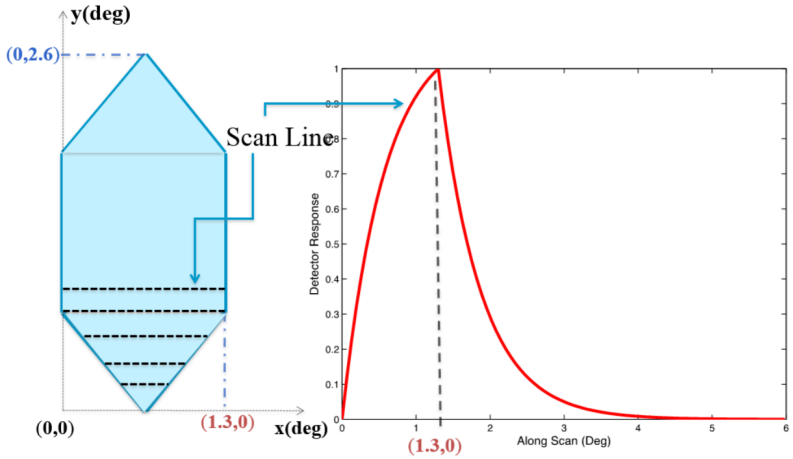
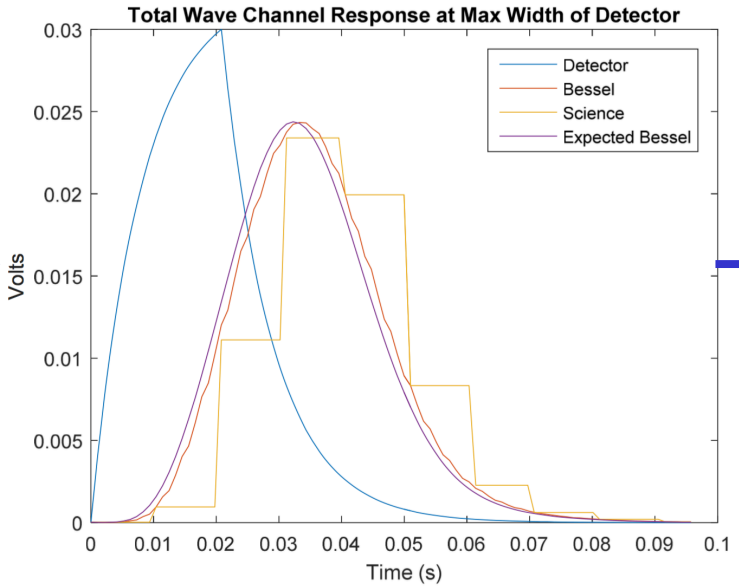
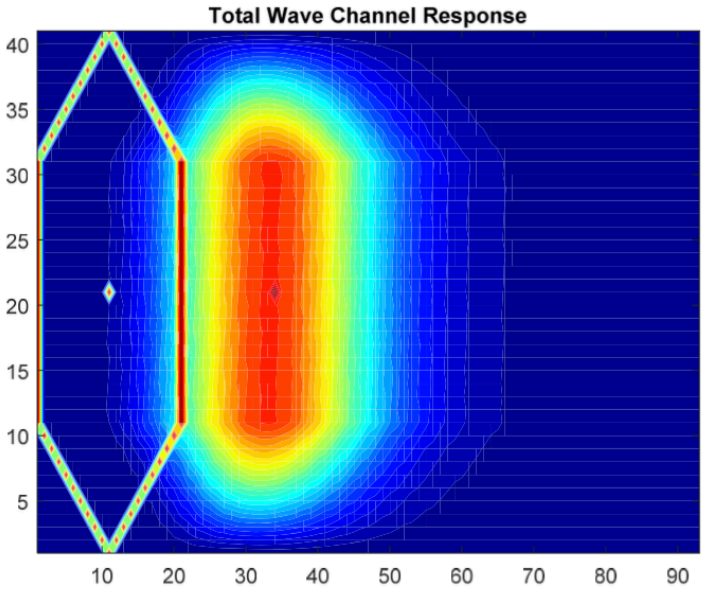
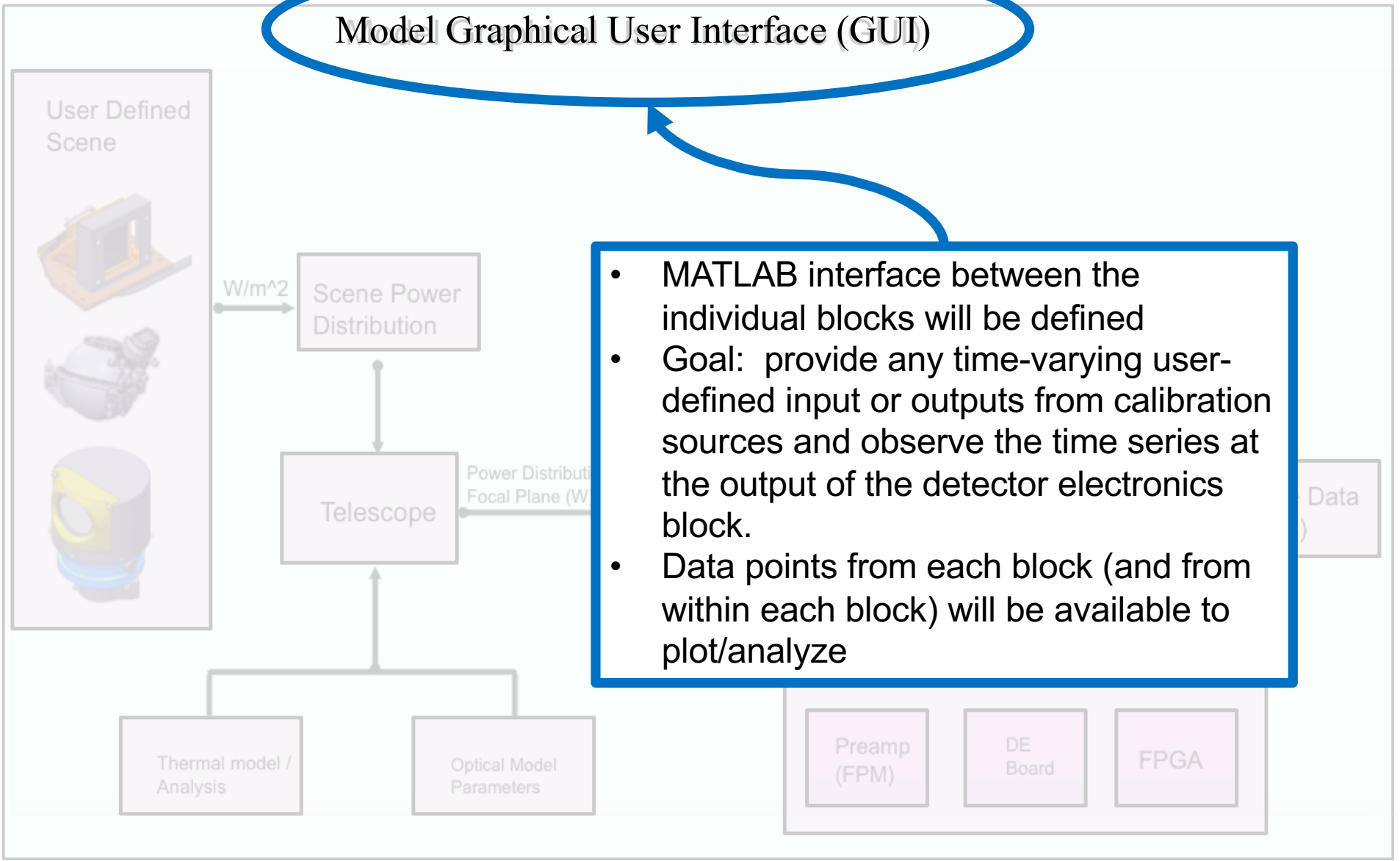






PSF Simulation

Graphical User Interface



- MATLAB interface between the individual blocks will be defined
- Goal: provide any time-varying user-defined input or outputs from calibration sources and observe the time series at the output of the detector electronics block.
- Data points from each block (and from within each block) will be available to plot/analyze

Current Status and Future Work

- Currently in Build 1 phase: All subassemblies are being developed in their respective platforms.
  - ✓ Design changes are being incorporated as engineering drawings become available
- Electronics model is nearly complete to the current design specifications
- Scene generator between calibration targets and telescope currently being defined and developed
- On-going thermal analysis supports and validates contractor's derived requirements for individual subsystems (ICT, telescope)
- Short-term studies that can influence instrument design are also being carried out in parallel
  - ✓ Stray light studies
  - ✓ SW filter heating and re-emission
  - ✓ Temperature variations in telescope baffles due to material change
  - ✓ Uncertainties in radiance arriving at telescope aperture due to:
    - View angles for all three telescopes to the sources.
    - Uncertainties in knowledge of the system parameters- ICT temp, paint absorptivities, BRDFs, etc.

Questions?